PROCEEDINGS OF THE SOCIETY

SEVENTEENTH ORDINARY MEETING

WEDNESDAY, APRIL 18TH, 1945

Sir HENRY DALE, O.M., G.B.E., M.A., M.D., D.SC., LL.D., F.R.C.P., *President of the Royal Society, in the Chair*

THE CHAIRMAN: Sir Edward Appleton needs no introduction, and as he has a long and important subject with which to deal, I shall not stand between him and his audience.

The following paper was then read:—

THE WORK OF THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

SIR EDWARD V. APPLETON, K.C.B., D.SC., HON. LL.D., F.R.S., *Secretary, Department of Scientific and Industrial Research*

As the war draws to its triumphant conclusion, the contribution of science to our victory becomes more and more impressive, and possibilities resulting from its application have caught the public imagination to an extent which was not achieved before the war. Few people doubted that we had the moral qualities to withstand the test of a long struggle, but there were doubts in some quarters whether we possessed the technological ability to enable us to devise, let alone produce, the weapons essential for success. There were, for example, people who, while admitting that Great Britain had made many important contributions to fundamental science, were pessimistic as to our ability to apply science. Our war record has confounded both groups of doubters. For six years practically the whole of our scientific effort has been in the form of applied science. Our success, therefore, has demonstrated that the British scientist is as good as any in the world in the applied field, and that the British industrialist is as well able as any other to appreciate and rapidly to adopt ideas which may be new to him. In war-time scale from the laboratory to production is reduced from years to months. The process therefore can be seen as a whole and the contribution of the scientist stands out in sharp focus. Although under peace conditions the stages of research, development and production are the same, the research effort is apt to be forgotten and seem less spectacular than in the quicker tempo of war.

In war again, everything which can be shown to be scientifically feasible and to be *needed* on military grounds becomes immediately *wanted;* and economic and social considerations, which must, under normal conditions, introduce a time-lag in the application of new discoveries, do not apply in war. Thirdly, in this war the scientist has been brought into contact with the users of his work to a degree which has never before been possible. He has been brought into counsel by the High Command and into intimate contact with the soldier, sailor and airman using his devices in actual operations and has often shared his perils.

The realisation of these facts has contributed to the widespread public interest in science and its application as evidenced by the numerous reports and books which have appeared on the subject and the debate in the House of Commons a year ago. In this debate the Government's policy regarding science and post-war Britain was announced by the Lord President. He then told Parliament that the Government was fully alive to the fact " that the winning of the peace, like the winning of the war, depended on the right use of science and scientific organisations." He further pledged the Government to a bold policy in backing research and to considerably increased financial support for it, provided there was evidence of readiness on the part of industry to use its results. He also made it clear that the Government intended to use, for implementing its policy, the existing machinery for research, *viz.*, the Department of Scientific and Industrial Research, whose work is the subject of this lecture, and the Medical and Agricultural Research Councils.

ORGANISATION

The Department of Scientific and Industrial Research was established by Order in Council during the last war, with its own vote and with the Lord President of the Council as responsible Minister, as a means of helping the country when peace returned.

By the Order in Council setting up the Department an Advisory Council was also constituted. The Council is a body of experts which advises the Lord President on the scientific policy to be followed and upon all important questions and developments falling within the scope of the department. It is constituted partly of eminent men of science and partly of leading industrialists, particularly those prominently associated with industrial research, with assessors appointed

by other Government departments. Recently two representatives of labour have been added. As its name implies, the Council is advisory and not executive, and the great influence it exercises depends largely on the fact that its members are selected by the Lord President as individuals and are not appointed as representatives of particular interests or organisations. Its vitality is maintained by appointing members for a definite period so that the constitution of the Council changes gradually. The present Chairman of the Council is Lord Riverdale.

The methods to be followed by the Advisory Council in carrying out its work are indicated in some detail in the White Paper which accompanied the original Order in Council. This stresses, for example, that the Council should draw up a programme of research to operate over a number of years, indicating where desirable the priority to be attached to various objectives. It also stresses the planning and co-ordinating functions of the Council, emphasises its power of recommending the initiation of proposals for new researches and of instituting enquiries to enable detailed proposals to be formulated.

With the exceptions of medicine and agriculture, the Department embraces in its scope all branches of natural science and their application to industrial processes, including the storage and processing of foodstuffs and the utilisation of timber. The application of science to the requirements of the fighting services and to war production is primarily of course, the concern of the Services and the Supply Departments, although during the war the Department has carried out a great volume of work on their behalf. Within its scope the Department's activities can be considered under three main headings :—

1. Research in the national interest for the benefit of the community as a whole and to meet the requirements of government departments.

2. The encouragement of research and the application of scientific knowledge in industry.

3. The encouragement of fundamental research at universities and elsewhere, and the maintenance of an adequate supply of trained research workers for laboratories of all kinds.

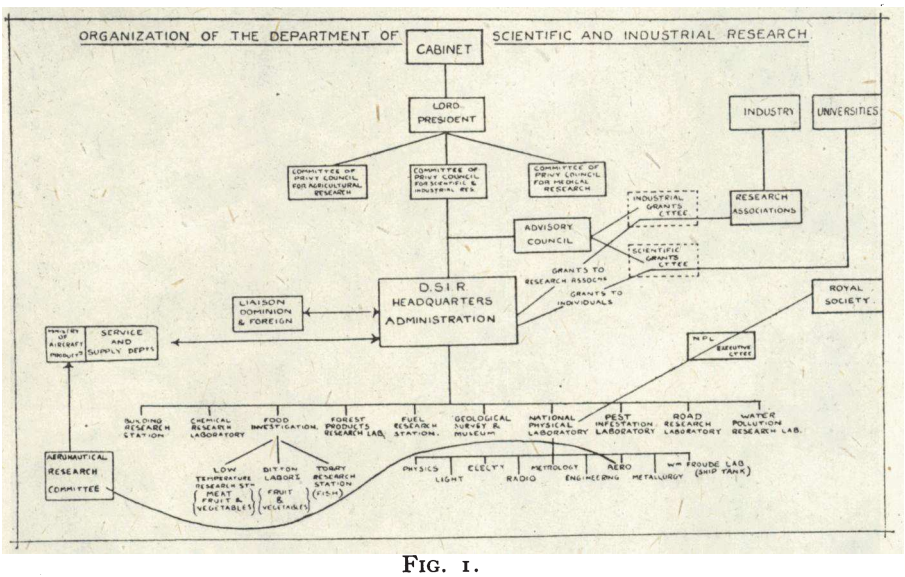

FIG. 1.

The Department has discharged the first of these three functions by establishing national research laboratories under its own control and direction, financed from its own vote. As government has entered more and more closely into the national life of its people, collaboration with the executive departments of State has become steadily closer and the provision of scientific knowledge upon which policy can be based has assumed greater and greater importance. The task of carrying out research to provide this knowledge is largely that of the Department's establishments. Although the Department has sought to encourage industrial research in many ways, the chief means adopted has been the

institution of a scheme for co-operative research associations. These are autonomous bodies formed to serve the needs of particular industries, financed by the industries themselves, but assisted by grants from the department related in amount to the sums raised by the industries served. The general provision for research at the universities is the responsibility of the University Grants Committee and not of the Department, but the Department has made many grants to individual workers in support of specific investigations of special timeliness and promise. It has also initiated a scheme of grants for the maintenance of post-graduate students to enable them to be trained in the universities as future research workers, together with a scheme of awards to more senior students who are likely to become pioneers or leaders of research in their various fields. The national research organisations established by the Department are for the most part under the immediate control of a Director of Research who is, in turn, advised by a Board or Committee appointed by the Lord President and, like the Advisory Council, composed of independent scientists and industrialists with assessors appointed by appropriate government departments and, in some cases, by the research departments of the Dominions. The only exception is the National Physical Laboratory. Until 1918, when it became part of the department, the National Physical Laboratory was under the control of the Royal Society, and the supervision of its scientific work continues to be exercised by an Executive Committee appointed by the Royal Society, which is accepted by the Lord President as a committee of the Department.

As permanent Secretary of the Department I am responsible to the Lord President for the whole of its activities.

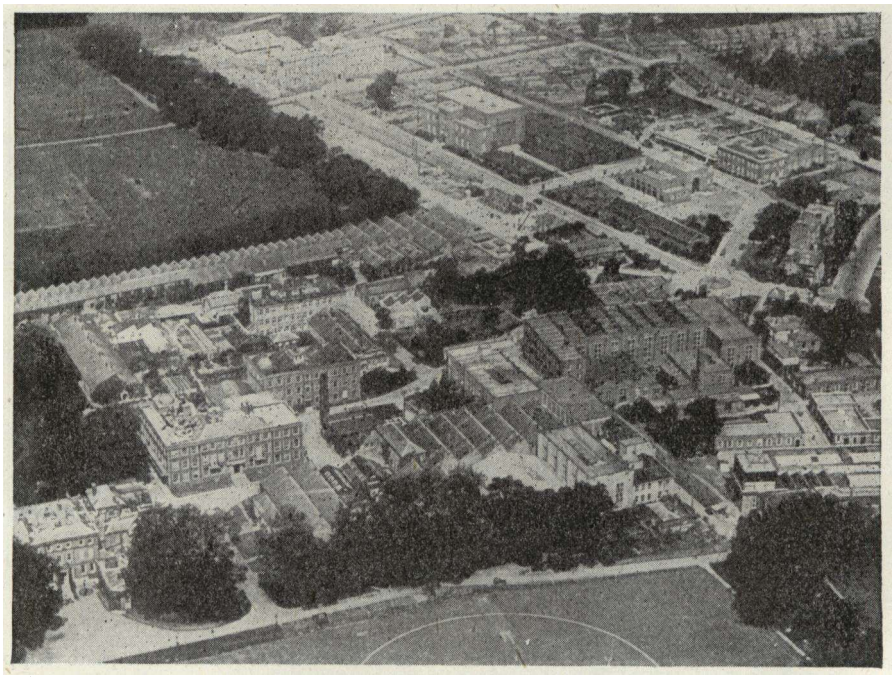

FIG. 2.—*Aerial view of the National Physical Laboratory, Teddington*

RESEARCH UNDER THE DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH FOR GOVERNMENT AND THE COMMUNITY

During its history the Department has established, or assumed responsibility for, the following organisations :—

The Building Research Station, Garston, near Watford.

The Chemical Research Laboratory, Teddington.

Food Investigation Stations :—

Low Temperature Research Station, Cambridge.

Torry Research Station, Aberdeen.

Ditton Laboratory, East Malling, Kent.

The Forest Products Research Laboratory, Princes Risborough.

The Fuel Research Station, East Greenwich, with local laboratories for the Physical and Chemical Survey of the National Coal Resources at Birmingham, Cardiff, Chester, Glasgow, Leeds, Newcastle-on-Tyne, Nottingham and Sheffield.

The Geological Survey of Great Britain (and the Museum of Practical Geology), Exhibition Road, South Kensington, S.W.7, with branch survey offices at Edinburgh, Newcastle and Manchester.

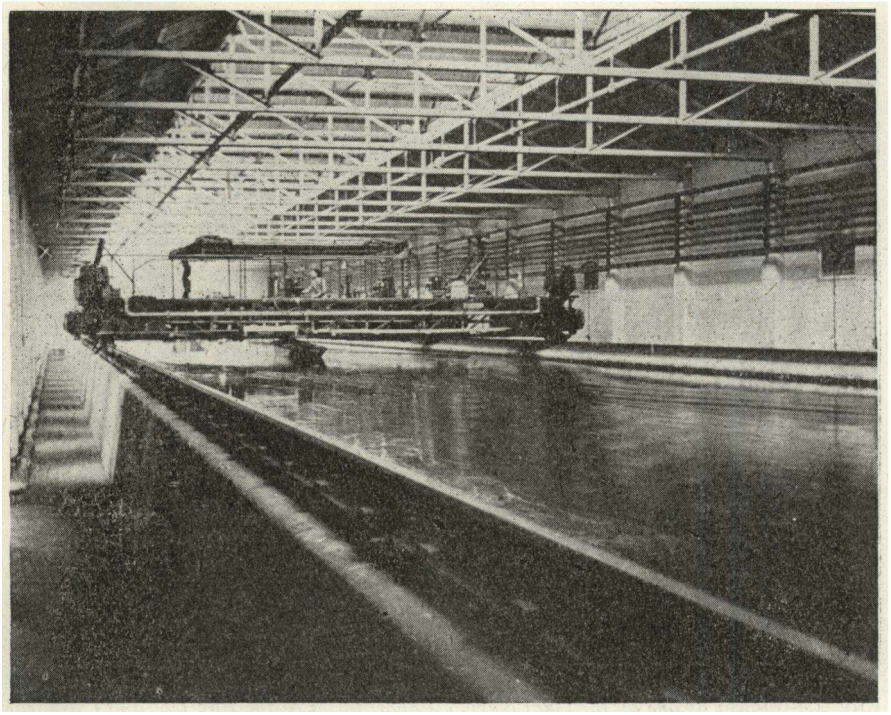

FIG. 3.—*One of the Testing Tanks in the Ship Design Division, National Physical Laboratory, showing the carriage towing a model of a ship's hull under test.*

The National Physical Laboratory, Teddington, with Divisions for Physics, Electricity, Metrology, Engineering, Aerodynamics, Metallurgy, Radio, Ship Design, Light.

The Pest Infestation Laboratory, Slough.

The Road Research Laboratory, Harmondsworth, Middlesex.

The Water Pollution Research Laboratory, Watford, with an out-station at Minworth, Birmingham.

The activities of these establishments are briefly reviewed in the following paragraphs :—

NATIONAL PHYSICAL LABORATORY

The National Physical Laboratory is the largest of the Department's establishments and employs a staff of well over one thousand. Its main function is research into methods of measurement upon which apparatus for research and for the control of industrial processes must ultimately be based. The laboratory is responsible for the maintenance of national standards of mass, length, and time ; for the various electrical units and for the accurate determination of the physical constants of materials and for the study of the properties of engineering materials and equipment. In its various divisions, tests and calibrations are also carried out on apparatus such as volumetric glassware, clocks and watches, thermometers, physical balances and optical instruments such as sextants, binoculars, etc. Under modern methods of production the gauges used in works for the construction of such things as motor vehicles or aircraft have for some purposes to be correct to one ten-thousandth of an inch. In checking these, sub-standards have to be available correct to one hundred-thousandth of an inch and to calibrate these the laboratory must be in a

position to measure accurately to within a millionth of an inch. For this purpose apparatus has been developed for measuring length in terms of the wavelength of light.

Under the Department's Radio Research Board the radio division of the laboratory has been responsible for a very complete study of the propagation of radio waves at all frequencies and for the investigation of the electrical state of the upper atmosphere and its effect on radio communication. In its application this work established the technique employed in the development of radio-location, and has enabled the most suitable frequencies for communication between different points at different seasons of the year to be forecast with considerable accuracy.

In the tanks of the ship division, which are waterways several hundred feet long, tests on models of every variety of marine craft can be carried out and from these tests the performance of the finished vessel accurately deduced. The reliance of British shipbuilders on this work is indicated by the fact that over 80 per cent. of new mercantile construction started in this country in the years before the war was based on " tank " tests carried out at the laboratory. It is estimated that continuous research carried out in the ship division over the last thirty years on the resistance to motion of ships has saved the shipowners about £1,000,000 per year in fuel consumption alone.

The laboratory is always ready to place its knowledge at the disposal of firms or associations and to carry out special investigations on their behalf, provided staff and equipment are available. During the war its energies have naturally been centred upon war-work but the consideration of post-war developments is far advanced. One such development is the establishment of a Mathematical and Statistical Division which will be available for consultation by workers in other government departments, universities and industry. It will provide computing services for them, undertake research into new statistical methods and their application in various problems, and the design and development of new computing machines.

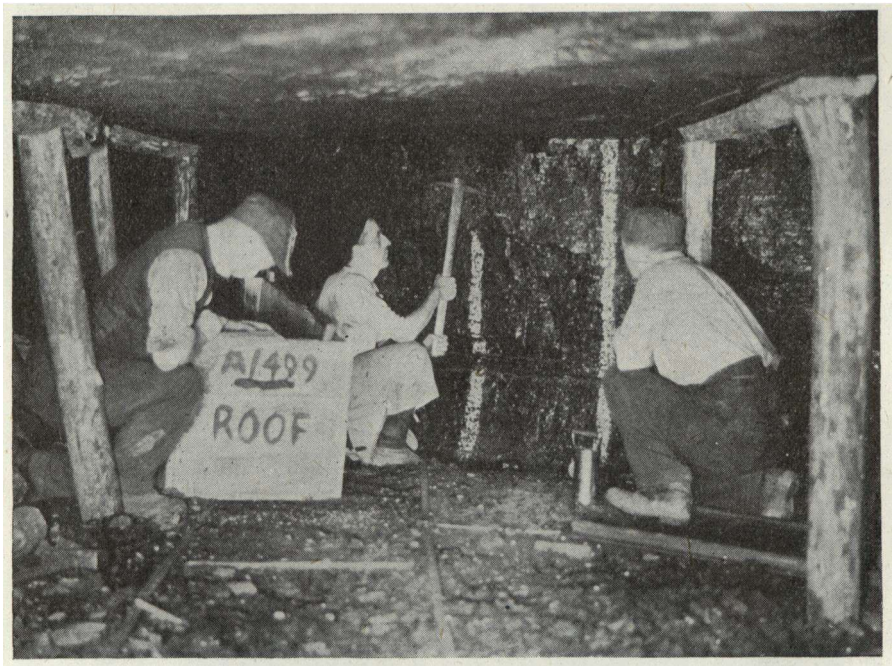

FIG. 4.—*Officer of one of the Coal Survey Laboratories of the Physical and Chemical Survey of the National Coal Resources taking a pillar sample from a coal seam for subsequent analysis*

FUEL RESEARCH STATION

In 1919, the Department established a Fuel Research Station at Greenwich as a national research centre for the study of fuel problems.

Its work has included investigations on the carbonisation of coal at high and low temperatures to improve the yield of gas and of smokeless and liquid fuels; on hydrogenation and other processes for the production of fuel oils from coal; and fundamental work on the chemical constitution of coal itself. In addition, coal cleaning, *i.e.*, the removal of non-combustible dirt from the coal as it comes up from the pit, and other methods of preparing coal for the market have been studied. Work has also been carried out on the storage of coal, the design of gas producers and pulverised fuel burners.

A most important section of work at the present time is that of the National Coal Survey, which is conducted at nine laboratories in the various coalfields with headquarters at the Fuel Research Station.

With the data collected by the Survey the quality and the most suitable uses of a coal seam can be assessed, and it is now possible to predict with considerable accuracy the properties of the coal at places where it is not yet accessible. In some fields, *e.g.*, in South Wales, maps have been constructed showing the places where coal of the same volatile content, for example, can be expected to be found. In some cases undesirable properties in a particular seam have been shown to be due to impurities limited to a narrow band. By avoiding such a band in mining the seam can be made to produce coal of first rate quality.

The Survey in conjunction with the Geological Survey is collaborating with the Coal Commission and the Ministry of Fuel and Power in assessing the reserves of coal of various types, and on problems connected with the production of open cast coal. It will be seen that the data collected by the Survey are essential in the planning of future mining operations on lines such as those proposed in the recent report of the technical experts of the Ministry of Fuel and Power.

Recently there has been a great and welcome development in organised research on coal as exemplified by an increase in the scale of working of the British Coal Utilisation Research Association (which is supported by the Mining Association of Gerat Britain), the formation of the Gas Research Board (a co-operative research organisation for the gas industry), and the British Coke Research Association. To co-ordinate the programmes of the Fuel Research Station and these other bodies a Standing Conference has been formed with Sir Harold Hartley as Chairman.

Building Research Station

Provision for national research into building problems requires no justification. In 1921, the department set up a Building Research Station to provide a national organisation for building research. Its programme covers the study of materials, both traditional and new, the acoustics of buildings, the exclusion of noise, heating, lighting and ventilation, the exclusion of damp and other matters concerning the comfort and efficiency of buildings for all purposes. Before the war the Station began work on the study of foundations, generally comprised by the term " soil mechanics," which has now been extended to deal with problems met with in the cutting of embankments and of drainage cuts such as those in the Fen district. Apart from its programme of general research the Station provides technical assistance, in one form or another, to all engaged in the industry. Several thousand enquiries on building problems and requests for special investigations or tests, received from architects, builders or contractors, are dealt with each year. The Building Research Station is studying new designs for houses for which purpose a number of experimental houses are being erected at the Station. These will be used for the examination of new ideas and the collection of data, particularly with regard to heating systems and their relation to house construction. The closest collaboration is being maintained with the Ministry of Works, the Ministry of Health and the Ministry of Town and Country Planning. The first fruits of this appeared in the Report of the Inter-Departmental Committee on House Construction, which is based largely on twenty years work at the Building Research Station. In this report it has been possible to set out for the first time in quantitive terms the desirable standards of house construction. This is a matter of great importance when novel forms of construction, not of a traditional character, are likely to be used on a considerable scale. The report is the first of about a score, some of which have already appeared, to be issued by the Ministry of Works, on post-war building problems, dealing with such subjects as plumbing, lighting, heating and ventilation, fire risks, etc. Another important step was the appointment by the Ministry of a committee to prepare codes of practice for building operations covering the whole range of building construction. In the preparation of both the reports and the codes, the Building Research

Station is giving its fullest technical assistance.

FOOD INVESTIGATION

The department's Food Investigation Organisation, which was set up in 1922, deals with the transportation, preservation and processing of foodstuffs and the methods of maintaining the qualities of freshness until the food reaches the consumer.

At the Low Temperature Research Station the fundamental causes of the decay of meat and bacon and methods of slowing down the chemical processes taking place and the growth of micro-organisms responsible for it have been studied. One result of this work has been a method of storage by which beef can be maintained in a chilled condition from ten to twelve weeks, long enough for it to be transported from Australia or New Zealand.

The Torry Research Station was opened in 1929 to enable the results of fundamental research on the preservation of fish to be applied at an important fishing port. Here it has been shown that by the process of " brine freezing " and storage at suitable low temperatures, fish can be kept in perfect condition from four to six months. This process can be applied both to whitefish and to herring. . Greatly improved designs of kilns have also been evolved for the kippering of herring, giving an improved product in less time and with less labour than with traditional designs of kiln.

Equally striking successes have been obtained in work on the storage of fruit and vegetables. One of the first successes in this field occurred in 1922, when unusually heavy losses, amounting to as much as £250,000, were reported on Australian apples. The scientists of the Low Temperature Research Station were called in to advise. They recognised the trouble as being due to a disease known as " brown heart " which they had been studying, which appears first as brown spots which later spread through the flesh of the apple. They knew that this disease was produced by suffocation of the fruit by the carbon dioxide produced by the apples themselves. What had happened was that the year had been marked by particularly calm weather and the usual ventilation of the holds in the ships had not occurred so that the cargoes had been suffocated. With the steps which are now taken to ventilate the holds, losses of this magnitude are entirely avoided.

The application of fundamental research on the physiology of fruit to its storage have been tried out on a commercial scale at the Ditton Laboratory, which is equipped with large-size cold stores in which storage conditions can be accurately controlled. One of these is an experimental chamber in which the conditions in a ship's hold in any part of the world can be reproduced. As a result of the work at our Ditton Laboratory an improved method of storing home-grown fruit known as Gas Storage, which depends on maintaining the correct percentages of carbon dioxide and air in the atmosphere of the store, has been developed. By this method Bramley Seedling apples can be kept in perfect condition for twelve months or more and Cox's Orange Pippins preserved with their full flavour until well after Christmas.

During the war most of the work on cold storage has been in abeyance and investigations have been directed, in collaboration with the Ministry of Food, mainly to the preservation of food by drying.

Storage of some kind is the only method by which Nature's gluts and shortages can be evened out, and whether we import food from overseas or grow it ourselves, some means of preserving it after the harvest until it is required will be essential. With the return of normal times it will be for the public, and particularly the housewife, to decide whether she prefers food to be preserved by refrigeration, dehydration or canning, on which we have also done a good deal of work. No doubt all three methods will be used. It must be remembered, however, that the housewife has not yet, due to the necessities of war, had experience of the best that dehydration can do in producing food of first class quality.

GEOLOGICAL SURVEY OF GREAT BRITAIN

The responsibility for the Geological Survey of Great Britain, which was established well over a hundred years ago, was assumed by the department in 1919. The advice of the Survey, based on the study of the geology of the country, which is continually being augmented, has been in continual demand by government and industry on the distribution of mineral deposits of all kinds, coal, iron, non-ferrous metals and on water supply problems. The Survey is almost invariably consulted before any important civil engineering work of any kind is begun, and during the war its assistance has been of the greatest importance in finding home sources for minerals essential for war production, which would otherwise have had to be imported. One example taken almost at random from the records of the Survey must serve to show

the close relationship between geological science and its application in everyday affairs. In providing a water supply for an important town a series of borings had been made but had yielded no adequate results. It was believed that the water-bearing clays had been reached and that further boring would be futile. Before abandoning the scheme, however, the Survey was called in and as a result it was deduced from the presence of certain fossils—the alleged playthings of the academic mind—in the bore that water-bearing levels had not, in fact, been reached and that the deepening of the bore should tap them. The engineers therefore persevered, with the result that a magnificent supply was obtained.

Time does not permit me even to summarise the work of our other establishments. They have, however, made striking contributions in their several fields. In the better utilisation of timber, in the treatment of water sewage and trade effluents, in the protection of stored products, especially grain, against insect attack and in chemical research, notably isolation of valuable chemicals from coal tar, and in the study of the problems of corrosion and its prevention.

Industrial Research

Besides carrying out research for the Government and the community the main function of the Department is to encourage industry to appreciate the value of research and, once having established the demand for it, to take all possible steps to ensure that the demand is fulfilled. The Department's task has naturally been easier with those industries, such as the electrical and modern chemical industry, which have grown directly from discoveries made in the laboratory. It has been harder with the long-established traditional industries into which the scientist often entered as a challenger of long accepted custom. It is not surprising that to some managements he appeared as a positive nuisance. Gradually, however, it began to be realised that the application of scientific knowledge is the only means by which the impact of competition could be met. Although in the long run research pays tremendous dividends, these are seldom achieved immediately, and although the cost of laboratory research is comparatively small its application often involves lengthy and expensive development, besides heavy outlay in the scrapping of out-of-date equipment. To a firm without considerable financial reserves, private research must often appear as a risky venture and beyond the means of many small firms which make up a large percentage of British industry.

These difficulties are met to a great extent by the co-operative research associations set up with the Department's help. Before the war twenty-one associations or similar organisations were serving the following industries :

> Iron and Steel ; Non-ferrous Metals ; Cast Iron ; Coal ; Electrical ; Cotton ; Silk and Rayon ; Wool ; Linen ; Leather ; Boot and Shoe ; Cocoa ; Chocolate and Confectionery ; Flour Milling ; Food Processing ; Laundry ; Paint and Varnish ; Pottery and Refractories ; Printing ; Rubber ; Welding ; and Scientific Instruments.

Since the war new research associations have been established for ship building, gas, coke, internal combustion engines and paper, while several others are under consideration. The total expenditure of the Associations has increased from £280,000 in 1934 to over half a million pounds in 1939, and it is expected to top the million figure this year. Further, substantial increases are confidently expected after the war. Several of the associations command very considerable incomes. That of the Coal Utilisation Research Association, for example, is over £200,000 per annum, while those of the iron and steel, cotton and electrical industries are well over £100,000 per annum and the Ship Building Research Association expects to start with an income near this figure. All the associations are aiming at increasing their scale of working very considerably after the war, and, in many cases, expect at least to double their income. This should go far to remove the chief criticism of the movement, namely, that the scale of working of many associations was too small to enable them to be fully effective. With greater resources they will be able not only to embark on longer range work, to which co-operative research is particularly adapted, but to improve their liaison services and other means for aiding their members in their day to day problems and assisting them in the application of the results of research. Larger incomes will also enable them to carry their work much further into the development stage than was possible before the war.

It is not often possible to assess the results of research in cash value, but two examples of attempts made some years ago to do this may be of interest. In 1933, the Iron and Steel Research Council calculated that the industry was saving coke worth £390,000 per annum in the production of pig iron, and coal worth

£1,300,000 per annum in production of finished steel as a result of co-operative research. In the same year, the Electrical Research Association calculated that, as a result of research costing £80,000, their industry was saving at least £1,000,000 per annum. However successful co-operative research may be, it can never be generally expected, especially in short-range research, to obtain results more quickly or to be more profitable than research carried out in a firm's own research department, with a staff in a position to appreciate the firm's problems to an extent impossible to any outside organisation. Even if a firm is too small to afford a complete research department of its own, it must at least employ some scientific staff if it is to get the full benefit from co-operative research; or indeed to use other facilities for obtaining scientific help to the best advantage. There are, however, no means by which payment from public funds to meet the research needs of individual firms can be justified unless the State also controls the results. Government has taken the only means available for encouraging private industrial research by the substantial remission of taxation on research expenditure announced in the last Budget.

A service the Department hopes to render to industry to an increasing extent is to help firms and trade associations from its long experience in organising research and its knowledge of the facilities available to decide how the funds which they are prepared to spend on research can most profitably be laid out.

Fundamental Research

In turning to fundamental research, I should like to say that I strenuously oppose the view that applied research undertaken for a practical end is any way inferior as a scientific activity to pure or fundamental research undertaken with no utilitarian objective. The history of applied science has proved, however, that fundamental research is the lifeblood of industrial progress and that the ideas which lead to the spectacular advances spring from it. As Sir J. J. Thomson once said " Research in applied science leads to improvements but research in pure science to revolutions." For these reasons the encouragement of fundamental research is important at all times, but it is particularly so to-day since it has been in abeyance in many fields during the war so that six years of progress have been lost.

While we believe in the Department that the scientific health of any research establishment of sufficient size will be the better for some fundamental research being conducted in it, nevertheless the best conditions of fundamental research are those which allow its leaders to follow any line which appears to them to be attractive and promising, and permit them to publish their results freely. These essential conditions are most easily achieved in the universities. At the same time some university departments are particularly well fitted for carrying out applied research.

The responsibility for general provision for university research is that of the University Grants Committee, but we are not thereby precluded from assisting specific activities. Accordingly, the Department has assisted research in universities and similar institutions by making grants to individual workers. Such assistance normally takes the form of provision for the employment of research assistants or for the acquisition of special apparatus. The grants are made on the recommendation of our Scientific Grants Committee, which is a committee of the Advisory Council, the main criterion being the " timeliness and promise " of the work proposed. The Department has also made arrangements for assisting work on specific items and, on the recommendation of our Boards or Committees, for items of work on their programme to be carried out extra murally. In fact, my own work at Cambridge on the study of radio propagation was assisted on the advice of the Radio Research Board. Again, the Department contributed to work at Cambridge on the production of intense magnetic fields, and to the provision of large-scale plant for the production of liquid hydrogen. Other examples of work carried out on behalf of the Department are investigations into chemical reactions at high temperatures, on the chemical constitution of coal and the study of fats and oils in relation to food processing. A third way in which the Department is brought into close contact with universities is in the scheme of maintenance allowances for post-graduate students, which allows them to be trained in the methods of research. Under this scheme young graduates work under the direction of a suitable supervisor for perhaps two years on a problem usually selected by him. The aim of the scheme is not to turn out a specialist in some branch of research, but to provide the trainees with a real understanding of the scientific method of attack and to give them

the degree of self-confidence necessary for the successful research worker.

Finally, close contact is maintained between our establishments and the universities by professors and other members of the staffs of universities serving on our Boards and Committees.

WAR WORK

During the war the whole resources of the Department have naturally been devoted to war work on behalf of the Services or the Supply Departments. Much of this work cannot yet be described for security reasons, but reference can be made to some of the Department's activities. In collaboration with the Ministry of Home Security, the Building Research Station and the Road Research Laboratory have applied their knowledge of materials, and in particular concrete, to the study of bomb damage and the design of air-raid shelters. When we passed from the defensive to the offensive the Road Research Laboratory played an important part by studying methods for destroying enemy buildings, and in the design of bombs for special purposes. At the Building Research Station the study made of the effect of enemy incendiary bombs on our buildings was adapted to the study of the effect of Allied bombs on enemy methods of construction, models of which were put up at the Building Research Station. In this sphere also the Chemical Research Laboratory carried out important work on the production of foams for fighting oil fires.

More nearly in its own field the Road Research Laboratory has made extremely valuable contributions to the design of runways for airfields, particularly for producing and rapidly laying temporary runways in forward areas. The Fuel Research Station successfully investigated methods for treating fuel for flame-throwers. The Station also produced a simple and effective means for preventing the emission of smoke by ships at sea, based on simple modification to the doors of marine boilers. This work should have important peace-time applications to land-boilers both in improving the efficiency of combustion and in preventing smoke pollution. The help of all the divisions of the National Physical Laboratory has been sought on many problems, for example, models of assault craft of all descriptions have been tested in the tanks of the Ship Division, including models of parts of the Mulberry Harbours.

The advice of the Water Pollution Research Laboratory was sought in the treatment of waste waters from Government factories. The laboratory also succeeded in producing by a chemical means satisfactory materials for converting sea water into drinking water in equipment which could be used in the rubber dinghies employed by airmen forced into the sea. The Forest Products Research Laboratory has co-operated closely with the Ministry of Aircraft Production in the study of plywood and adhesives used in the construction of wooden aircraft. On the food front reference has been made to the important part played by the Department in the study of dehydration and other problems. The work carried out at the Chemical Research Laboratory on the production of food yeast and its possibilities in providing cheaply and rapidly a supply of proteins enriched with vitamins for under-nourished populations has recently been described to the Society.

The Research Associations have also made important contributions of which the following are examples. The Cotton Industry Research Association has produced a waterproof cotton cloth, the fibres in which are twisted in such a manner that they swell immediately when they come into contact with moisture and so block up the interstices of the cloth and make it water resistant without any other waterproofing treatment. These cloths, while they are impermeable to water, allow the air to pass through them. They are now being produced by a section of the industry. A hose-pipe has been made from them which will stand up to the Home Office tests and garment cloths are being made for the clothing of airmen who may be immersed in sea water. This is an invention which should obviously have a great future after the war. The processes developed by the Wool Industries Research Association for preventing the felting and shrinking of woollen goods have been employed by the Army in the production of under-clothes and socks for the troops with excellent results. The Launderers' Research Association has advised on field laundries and the best means of washing without or with very little soap. This Association also has devised a method of treating blankets with oil which has done much to reduce cross-infection in hospital wards. The Paint Research Association has done valuable work on the improvement of camouflage paints.

THE FUTURE

Directors of Research and their respective Boards are now considering how their work should be adapted and re-orientated to meet

post-war needs and what expansion is necessary. Our Advisory Council has instituted enquiries to review the facilities in this country for research into mechanical and civil engineering and in what directions they need extension. An enquiry is also being made into the probable requirements of industry after the war for routine testing and how this can best be met. The Advisory Council also felt strongly that the Headquarters of the Department should be strengthened by the setting up of an Intelligence and Information Division with the specific task of assisting those seeking the Department's help on the best means of attacking their research problems, and of helping to ensure that opportunities for applying new knowledge are not lost. Such a division is already in course of formation. It is in intimate contact with the recently-formed research department of the Federation of British Industries, and is collaborating closely with the Joint Research Council of Manchester University and the Manchester Chamber of Commerce, which, I trust, may be a forerunner of similar bodies established in the great industrial centres of the country to encourage research in industry.

I have told you a good deal of what the Department has done in the past and I hope that I have convinced you that what we did was well done, and I have surveyed very briefly our war effort. Now, when our war tasks are ending, we have been examining ourselves and planning for the future. We believe that in general our organisation is sound, and there are many important jobs to be done. After the war we want to expand our facilities to tackle them on the same general plan as we have followed in the past. We shall not ask for money and then think out ways of spending it—that is quite the wrong method. We shall select our problems and, on the grounds of their importance, ask Parliament to vote us the money to undertake them, confident in our ability to improve the standard of life of the citizens and to increase our national prosperity.

DISCUSSION

THE CHAIRMAN : I know that you will wish me to thank Sir Edward Appleton, on your behalf, for the comprehensive exposition he has given us of the work of the great department of which he is the chief Executive Officer. Experience seems to show that this country almost needs a war to be convinced of the value of science. It was in the middle of the last war that the Department of Scientific and Industrial Research came into being, and perhaps we might say that it almost required another war to make the nation fully conscious of the need for science and the need for organising scientific effort.

In connection with the establishment of the Department of Scientific and Industrial Research during the last war there is one acknowledgement which I think it would be very appropriate to make. There was one man in this country (until a few weeks ago) to whom the nation's debt for his encouragement of science has not been adequately paid ; I refer to the late Earl Lloyd George. He was really the first influential politician in this country to see what the support of science by the Government might mean. As long ago as the first decade of this century he had taken the first step in the creation of a Development Fund which has supported a substantial amount of research in agriculture and marine biology. The next step was a by-product of Earl Lloyd George's Insurance Act, when some wise person said, " It is no good pouring medicine down people's throats ; you must do something for medical research." So in 1913 a Medical Research Committee came into being which was to provide a model for the structure which was, three years later, to emerge over a wider area of scientific research, stimulated by the needs of war, namely, the Department of Scientific and Industrial Research. The Medical Research Committee was the first important organisation, administering substantial funds provided by the public, to consist not of Government officers but of distinguished scientific experts. That analogy was therefore ready for adoption by the Department of Scientific and Industrial Research in 1916.

There is another analogy which, during the greater part of its career, the Department has followed. The first Secretary appointed by the Medical Research Committee was not an experienced Civil Servant, but a distinguished scientist with direct experience of medical research and great administrative ability, Sir Walter Fletcher. After its initial period, the Department of Scientific and Industrial Research had, in succession, as its chief Executive Officers, Sir Henry Tizard, Sir Frank Smith and Sir Edward Appleton. I think that that was a very wise policy to which a large part of the success of the application of these Government funds has been due.

I should like to register my very convinced

agreement with the view that the attempt to distinguish between fundamental and applied research is really largely a matter of words. There is, I think, another and more significant distinction which we ought to keep in mind: it is not so much a distinction between fundamental and applied research as between organised and free research. I think it is necessary, greatly as the country has benefited by the use of large Government resources for organised research on a large scale, that we should still have a good margin of research which is absolutely free from any kind of organisation.

In that connection Sir Edward Appleton has made proper acknowledgement in his paper of the Government's demonstration that it is alive to the fact that research, in general, needs far more financial support than hitherto. That has shown itself not merely by the provision of additional funds for administration by the three great Government research Councils, the Department of Scientific and Industrial Research, Agriculture and Medicine, but by the substantial additions already made, as an earnest of more to come, to the University Grants Committee, and by the quite substantial additional grant (not so much as we asked for but as much as we expected to get) to the Royal Society for administration in support of research which is absolutely free from any implied restriction to practical objects or any Government organisation or control. That, I think, is a thing we ought to acknowledge. I should like to make it clear, however, that I am not running into the error of assuming that research thus organised—whether for industrial or for Government purposes—cannot make real contributions to fundamental knowledge. I hope that in this country we shall create an opportunity even more than in the past for research men of the highest type to bring their ideas to bear on industrial problems, but I hope that nevertheless they will be left largely free to make their contribution to fundamental research. I ought perhaps, in urging the claims of possible fundamental research, to mention the fact that my own research opportunities have come from both sources. I worked for ten years in industry and then, for the rest of my active career, in a Government research laboratory; and, whatever its merits or demerits, I believe that my work cannot be accused of having been restricted to any immediately practical objective; for what it was worth, it was essentially fundamental.

Mr. E. W. M. HEDDLE, M.C., M.A., B.SC.: There is just one point about which I am not quite clear. At the beginning of the war I was called upon to train girls to undertake engineering inspection work. One group of these people was to be trained in metrology and was to be employed in the testing of fine gauges, and the firms concerned laid down that the apparatus used should estimate to five-millionths of an inch. In the paper, however, the lecturer lays down a limit of one hundred thousandth of an inch for the National Physical Laboratory. I do not know whether those firms making fine gauges had a higher standard but I should not think so.

One other thing I should like to mention is that the lecturer told us that the Torry Research Station had named its trawler "City of Edinburgh." May I point out that Torry is at the mouth of the river in Aberdeen? Edinburgh and Aberdeen are rival cities.

Mr. A. E. PARNACOTT: I suggest that through invention is the one and only way we can lead in industry, not only of our final products but also of the plants for their productions, assemblies and deliveries. If that had been done before and if it be done in the future we may have a chance of underselling Germany; her aggregative states are not yet British Colonies! The fact that Napoleon said that we were a nation of merchants means that the business-men of this country, normally and ordinarily speaking, do not mind where the goods are made so long as there is profit!

I should like to point out that before the outbreak of the 1914-18 war there was a man who did great work in connection with artillery shelling aircraft. He is dead now, unremunerated and unrecognised, but the work he did was towards the practical automatic placing of the shell-bursts when there was not time for predictor methods. I think that our habit of laughing at every departure from recognised practice has cost lives and this country very large sums of money indeed. I would also point out that to-day the steam-locomotive does not use 5 per cent. of the energy generated by the coal it uses for pulling itself and train. In the cases of electric light, power, and the railways in this country not 20 per cent. of the heat energy generated is used.

Dr. B. J. A. BARD (Industrial Research Secretariat): The experience of some research associations is that in some instances small

firms consider that they have done their duty to research by subscribing to those associations instead of setting up their own research departments as well. Could the lecturer say a word or two about that point ?

Dr. KATHLEEN LONSDALE, F.R.S. : I should like to ask one question on behalf of those engaged in the new science of X-Ray crystallography. I have talked to a large number of young people engaged on this work and they say that it is almost impossible to obtain X-Ray apparatus exactly suitable for the job because the manufacturers of X-Ray equipment are not interested in making a few pieces of special apparatus except at a prohibitive price. Is there any possibility of the lecturer's Department providing apparatus for industrial research at a price which industry can afford ?

Mr. P. L. DEAN : I should like to know whether the lecturer thinks that research would be more readily accepted by industry if industry were run by younger executives.

Mr. J. P. COOK : May I ask whether the lecturer has any views on the desirability of revising the patent system of this country ? Our patent system seems rather out of date and in some respects tends to discourage rather than to encourage inventions.

Sir EDWARD V. APPLETON : I do not propose to deal with the question of patents. There is a committee considering the matter at the moment. The question really does not come within the scope of scientific research. The fact that patents are obtainable may act as a spur to inventors but I do not think they act as a spur to scientific investigation.

The next question was about the importance of young people taking part in the formulation of policy. I shall answer that question by saying that I think the important thing in industry is to get scientific people on the various boards of directors, whether young or old.

In reply to the question about X-Ray tubes, I sympathise with the speaker in her difficulties and I will certainly investigate the matter.

On the subject of the efficiency of the steam engine it must be remembered that there is an important law known as the second law of thermodynamics concerning the turning of heat into work. Although it is sometimes thought that by research we can obtain 100 per cent. efficiency I am afraid that this law of nature shows that we cannot !

I rather think that the speaker who referred to fine gauges is using much smaller tolerances than are usual in industry. Measurements are however made at the National Physical Laboratory to within one-millionth of an inch.

The point about the " City of Edinburgh " and the Torry Station's proximity to Aberdeen had not escaped my notice !

THE CHAIRMAN : On behalf of the meeting I should like to propose a hearty vote of thanks to Sir Edward Appleton for his paper.

The vote of thanks was accorded with acclamation.

On the motion of Major W. H. CADMAN, M.B.E., B.SC., F.R.I.C., F.C.S., a vote of thanks was accorded to Sir Henry Dale for taking the Chair, and the meeting terminated.